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Indonesian Permanent Single GPS Station Potential for Precipitable Water Vapor (PWV) Calculation

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Abstract— *The establishment of a GPS Permanent Station network in Indonesia began in 1996, and is now known as Indonesia continuously operating reference station (INA-CORS), its management authority under the Geospatial Information Agency (BIG). Based on information from BIG, data of 2016, the distribution of CORS in Indonesia has as many as 135 stations. INA-CORS is built, has the main objective is to maintain national geodetic reference frames in active seismic zones for survey and mapping purposes, as well as basic tasks and BIG functions. In its development, based on (BEVIS 1992) RINEX data is not only to determine the position as a reference geodesy for survey and mapping, but also to determine the water vapor for meteorological purposes. The observational accuracy is similar to the results obtained from other methods. Water vapor plays an important role in the atmospheric system because it affects the balance of elements and energy in space, so it is worth developing.*

Keywords— ***INA-CORS, troposphere, radiosonde.***

I. INTRODUCTION

Global Positioning System (GPS) technology has been known only for the purposes of positioning, and navigation in general. In addition to mapping and navigation purposes, this technology also has the competence for various studies of the earth (earth sciences). One of the most reviewed is the GPS application to get the volcano. In addition to the field of volcanology, there is still much that can be expressed through this GPS technology, such as the content of air vapor (moisture content) in the atmosphere (Bevis et al., 1992; Duan, et.al., 1996; Tregoning, et al ., 1998; Ware, et.al., 2000 and Liou, et.al., 2001) known as the Meteorological GPS Project.

As has often been the case in various literature, the working principle of this GPS technology is GPS satellite signals located at an altitude of approximately 20,000 km in space. By having a receiver, information about the position (horizontal and vertical) in various coordinate systems will be known. This is a basic function of GPS technology and can be applied for positioning, construction activities, and mapping surveys.

From this basic function then raised various other functions of the direction, estimating the distance and time (for the purposes of navigation), speed and acceleration and so forth (Abidin, 1995). Its applications include land, sea and air navigation, research on earth plate movements (geodynamic studies), volcano observations (volcanology studies).

An important aspect of this GPS technology is accuracy (accuracy), as it relates to the "truth level" of the GPS observation information. Various ways are developed to improve the accuracy of information from the view with GPS technology, among others: improve the ability of the recipient, develop GPS methods, more sophisticated and so forth.

With the above advances and combinations, the accuracy of the GPS observations can be improved. This needs to be done that has been done by GPS satellites up to the receiver (recipient) so that various studies are done to

eliminate these errors. The various errors that arise and their effects have been discussed by Abidin (1995). One method that has been successfully developed is the Differential GPS method that is the method of determining the operating point dot that serves to estimate the magnitude of GPS signal errors at a certain time.

With this method reversed, that is by comparing the observation results with the control point coordinates, then the component of the error signal can be estimated. With what can be tried price data such as temperature, air pressure, then the air-vapor content can be determined. This paper attempts the method of water vapor modeling that has been implemented in various places and the possibility of its application in Indonesia.

Components of Troposphere and Water Vapor

The troposphere layer is the layer closest to the surface of the earth. This layer has a thickness of approximately 8 - 10 km above the surface of the earth with the main components of gas Nitrogen (78%) and Oxygen (21%) (Miller, et.al., 1983). The water vapor contained in this layer is quite small in quantity (less than 4%) but plays an important role in the process of decelerating the propagation of electromagnetic waves known as a tropospheric delay.

In addition water vapor also plays an important role in the process of determining the weather, is a radiation absorber that affects the energy balance in the atmosphere, and plays a role in the release of latent heat from the condensation process so as to maintain processes that occur in the atmosphere (Miller, et.al., 1983). To that end, various methods were developed to estimate the amount of water vapor in the atmosphere.

Currently, there are several methods used in the determination of water vapor content in the atmosphere, namely: radiosondes, water vapor radiometer, special sensor microwave imager, TIROS operational vertical sounder, SAGE II and so forth. Popularly used are radiosondes and VWP. But these two methods have the disadvantages of high cost, lack of spatial and temporal resolution, and less good for areas with high rainfall (Liou, et.al., 2001). For that developed a method by using GPS.

II. DATA DAN METHOD

The slowing of the GPS signal, which is one type of electromagnetic wave, due to through the troposphere layer can be estimated in processing GPS observation data. The tropospheric delay consists of two components: the dry (hydrostatic) component, which accounts for about 90% of the total throttling, and the moist components that depend on the air humidity. The wet component provides a much larger component of the error than the dry component since it is more variable spatially and temporally.

In order to determine the magnitude of tropospheric correction in GPS data processing, usually used existing troposphere models such as Hopfield, Saastamoinen, and Black. In the case of determination of moisture content, the model is used by reversing known parameters and variables and estimating the total value of zenith delay (ZTD) ie the magnitude of the delay from the vertical direction of the signal to the receiver. This value is a composite of the wet component and dry component values. In practice, the wet component is harder to determine, so the most common is to estimate the value of a dry component known as zenith hydrostatic delay (ZHD). So the equation is obtained:

$$ZWD = ZTD - ZHD \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The value of ZHD itself is estimated by formula (Elgered, et.al., 1991) :

$$ZHD = \frac{(2.779+0.0024)*Ps}{F(\varphi,H)} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where:

- Ps is the total air pressure on the earth's surface,
- F is the variation of the Earth's gravitational acceleration at the point with the latitude (φ) and height (H) of the earth ellipsoid model.

Next, is calculate the value of integration of water vapor (Integrated Water Vapor = IWV) that is the amount of water vapor calculated from GPS signal in one air column. To calculate the moisture content (Precipitable Water Vapor = PWV) is to divide the IWV value by the density of water.

$$PWV = \frac{10^6}{\left(\rho w Rv \left[\frac{k3}{Tm+k'2}\right]\right)} * ZWD \ldots\ldots\ldots \quad (3)$$

Where:

ρw = water density,

Rv = constant for gas

k'2 = 22.1 K / hpa

k3 = 3.739 * 105 K2 / hPa

Tm = 70.2 + 0.72 * Ts

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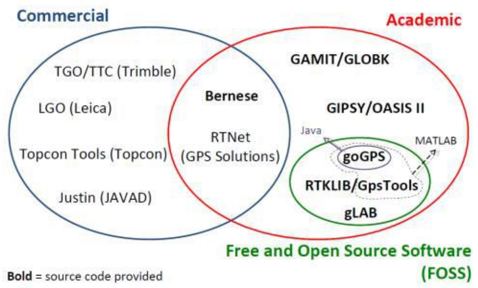
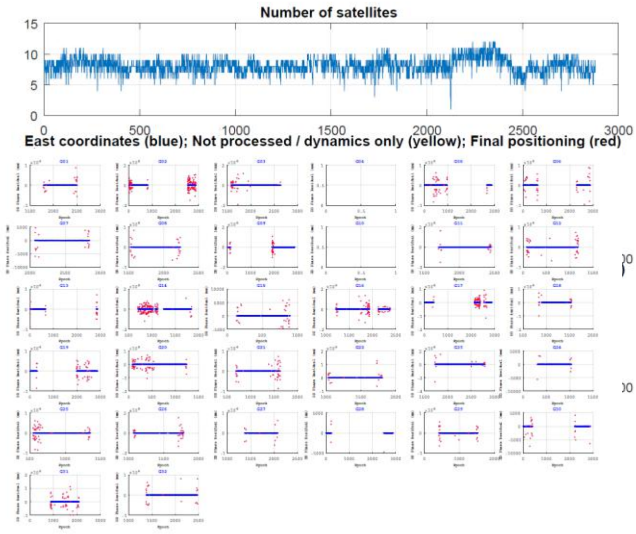
with Ts is the temperature at the surface (Bevis, et.al., 1992).

Actually, a lot of software for data processing Rinex format to determine the positioning and navigation, ranging from commercial to open source. Among others, RTNet, Trimble, Bernese are commercial categories and GAMIT, GIPSY-OASIS II and opensource categories are RTKLIB, GPSTk, GoGPS. For the purposes of this research, the software used is goGPS version 0.5.1 Beta 3 with PPP strategy, combined with Matlab R2016b version development of goGPS started in 2007 at Politecnico di Milano, Como campus (Italy).



The The first version of goGPS MATLAB was published as free and open-source software in 2009, under a GPLv3 license; the software has evolved steadily through the years, improving stability and performance. The development of an alternative version of goGPS, written in Java and published under a LGPLv3 license, was started in 2010 with the aim of providing a positioning library in a coding language more suitable for the implementation of positioning Web services (Realini et al. 2012). It is important to note goGPS does not require MATLAB special supporting toolboxes. The user only requires the Instrumental Control Supporting Toolbox when the connection of a GPS device to a COM port is desired. In this paper, we focus on the MATLAB version, from here on simply referred to as "goGPS".

goGPS processes single-frequency (L1) code and carrier phase observations either by epoch-by-epoch least squares adjustment (LSA) or by an extended Kalman filter (EKF), applied to either undifferenced or double-differenced observations, to produce solutions based on multiple epochs. goGPS can apply different observation-weighting strategies: based on satellite elevation or on tailored weight functions that exploit the known signal-to-noise ratio characteristics of low-cost receivers. The modular design of the goGPS EKF allows for the seamless addition of optional external data sources, e.g., pseudo-observations interpolated from digital terrain models (Realini and Reguzzoni 2013).



III. RESULT AND DISCUSSION

By using goGPS software and PPP strategy, to obtain ZTD value, the results obtained related to satellite measurement and constellation are presented in the following figure: :

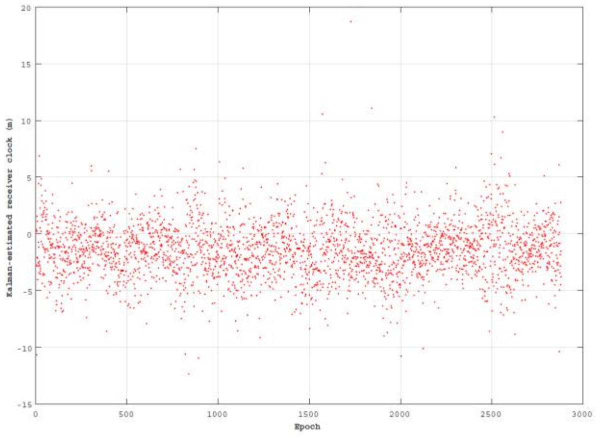
The figure shows the results of the CMAK station positioning measurement process in a day, on December 19, 2015, with a duration of 30 seconds. So in a day, very dynamic one position moves in different directions.

A GPS receiver determines the travel time of a signal from a satellite by comparing the "pseudo random code" it's generating, with an identical code in the signal from the satellite. The receiver "slides" its code later and later in time until it syncs up with the satellite's code. The picture above is a residual GPS code view with outlier, from each satellite GPS of 32 satellite. This information to explain for the change in position satellite within the orbit.

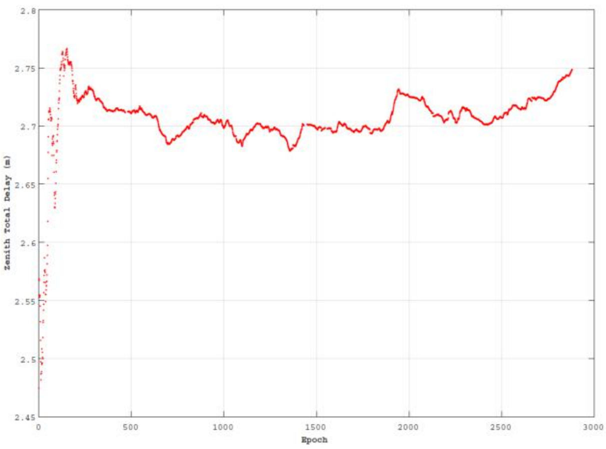
The carrier phase measurement is a measure of the range between a satellite and receiver expressed in units of cycles of the carrier frequency. This measurement can be made with very high precision. The picture above is a residual GPS carrier phase view with outlier, from each satellite GPS of 32 satellite.

And this below, a picture show Kalman estimated receiver oclock for the processing Rinex data, plotting with epoch as time for constellation satellite.

For positioning and direction are controlled by as many as

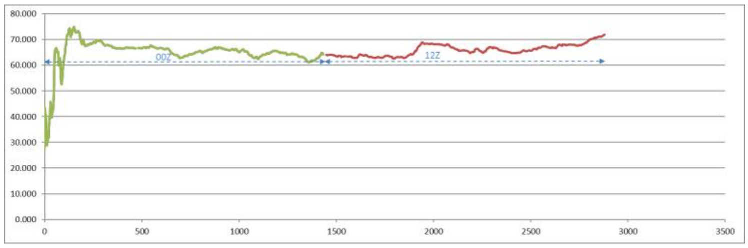


32 satellite GPS circulating in orbit.In the process of measuring the position, the correction process is done to eliminate noise and noise it is Zenit Total Delay (ZTD).



GPS delays are related to water vapor. Using meteorological observation data on the surface or modelling, ZTD GPS is converted to Precipitation Water Vapor (PWV). Water vapor is a very important element of the atmosphere. One of its roles is Water vapor is crucial in forecasting precipitation and important to atmospheric dynamics. Then the other water vapor size is very rough in space and time, for example, the measurement of water vapor uses Radio Sonde, which in a day only get data twice.

The figure shows the result of GPS PWV from CMAK station in one day, every 30 seconds ie on December 19, 2015. The green color is the period from 00:00 AM to



11:59:30 AM we call 00Z - UTC and the red color is from 12.00.00 PM to 23.59.30 PM, called 12Z - UTC

At 00Z, Max value: 74.942 mm at 1:15:30 AM and min value: 27.964 mm at 12:00:00 AM, and average PWV value of 64.8948 mm. While at 12Z Max value: 71.962 mm at 11:59:00 PM and min value: 62,601 mm at 2:58:30 PM, average 65.999 mm.

At 00Z shows an interesting pattern, and this is known at a distance of 40-80 minutes the value of PWV decreases and increases. And at 00Z trend the PWV value tends to

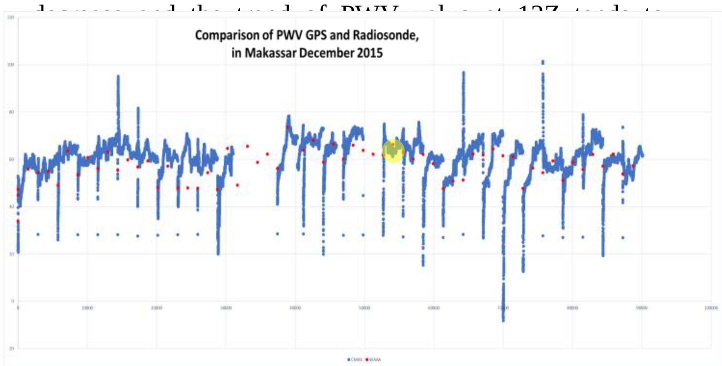


Figure above shows, is a comparison between Precipitation water vapor (PWV) data, from radiosonde measurements at station WAAA , and GPS observations from CORS at station CMAK, both stations are located in Makasar City for December 2015. Radiosonde data is obtained from HTTP: // weather.uwyo.edu and CORS data obtained from BIG.

PWV determined by GPS and radiosonde for one month provide a good pattern and tend to be the same..

IV. CONCLUSION

At 00Z, Max value: 74.942 mm at 1:15:30 AM and min value: 27.964 mm at 12:00:00 AM, and average PWV value of 64.8948 mm. While at 12Z Max value: 71.962 mm at 11:59:00 PM and min value: 62,601 mm at 2:58:30 PM, average 65.999 mm. INA-CORS data processing to get ZTD in a day indicating the value of PWV at the lowest point and at night the value of PWV at the highest point.

PWV determined by GPS and radiosonde for one month provide a good relationship, and data processing from INA-CORS has the potential to obtain information to study climate and environmental science.

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